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DESIGN OF A SAFETY MONITOR SYSTEM FOR HIGH EXPLOSIVES MACHINING

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ABSTRACT

A computerized Safety Monitor System was recently designed for and installed on a Bostomatic Mill/Lathe at Site 300. This report includes a brief description of previous safety modifications made to the machine and describes the objectives, design features, system analysis, hardware, software, and possible industrial application for the Monitor System. The Appendices provide details on the system analysis and the start-up procedure for the system.

INTRODUCTION

The High Explosives Machining Facility (HEMF) at LLNL's Site 300 has the charter to machine high explosive materials as safely and reliably as posssible. To support this requirement, we designed and built a Safety Monitor System for a Bostomatic Mill/Lathe located in Bldg. 806 of the HEMF area.

BACKGROUND

The Safety Monitor System is the most recent of a number of safety modifications made to Computer Numerical Control (CNC) machine tools used to machine high explosives in the HEMF area of Site 300. In the summer of 1978 we began to enhance the safety of several CNC machine tools by designing several safety modifications into the machine control system. These safety modifications monitor and control critical machining parameters such as chip thickness of the part being machined, tool force, spindle RPM, and the tool's surface feet per minute speed.

These safety modifications work as follows. Two pre-settable "flags" or levels of operation can actuate each safety circuit in a similar fashion. For instance, if the tool force exceeds the first level during a machining cycle, a "Feedhold" command is generated and automatically attempts to correct the situation by returning the tool force to a safe level. If this action is unsuccessful and a second higher level is exceeded, the danger is considered to be imminent and an "Emergency Stop" (E-Stop) command is generated which initiates a safe shut-down procedure of the machine tool system.

We also modified the control system so that each machine may be remotely controlled from a protected area thereby insuring machine tool operator safety. Finally, all electronic equipment in the machine room is purged with a positive pressure of clean air to insure that explosive dust will not build up in areas where it might spark and explode.

OBJECTIVES

We recently designed and installed a Safety Monitor System on a Bostomatic Mill/Lathe that had previously been modified with the above-mentioned safety features. The system monitors critical machine parameters during the actual machining process and provides a history for real-time and post-event examination, serving the same function as an airplane flight-recorder.

Like a flight recorder, the Safety Monitor is strictly open-loop, that is, it monitors the system data but has no control over the process. During the machining process, the Safety Monitor looks at and stores critical preselected machining parameters from the following areas (Table 1 outlines the parameters that are monitored and stored):

- Absolute data display
- Axes control data
- CTC mode
- Machine control data
- FH/ES status

The real-time machining data is transferred from volatile semi-conductor memory to a floppy disk if an E-Stop condition is detected or if the monitor program loses communication with the data acquisition program and no data is received for a time period equal to two sets of data.

DESIGN FEATURES

The Safety Monitor was designed to provide the following:

- Data Collection The present system has the capacity to examine 512 bits of digital data. The final set of data selected to be monitored on the Bostomatic Mill/Lathe requires less than 300 bits. A complete set of data is monitored and transmitted to the remote control station 8 times per second.

- Real-Time Display After the real-time data is received from the local control station in the machining room, it is processed and displayed on a VuRam CRT screen. The machine tool operator in the control room monitors all of the machining parameters on the screen and can quickly evaluate the status of the machining process.

- Reliable Data Storage Up to 15 minutes of real-time data is stored in volatile semi-conductor memory which is structured to function as a circular buffer. After the circular buffer has been filled, it continuously refreshes itself by writing the next byte of data over data that was stored 15 minutes previously. An Uninterruptable Power Supply (UPS) at the remote control station insures that the real-time data may be reliably transferred from semi-conductor memory to disk if a power outage occurs.

- Post-Event Data Analysis The Safety Monitor can aid in the post-event evaluation of the real-time data. We designed a software program that retrieves data and displays it in tabular form from any point in the 15-minute interval.

- Friendly Human Interface A conscientious effort was made to consider the human engineering aspects of this system. The engineers worked with the machine tool operators, seeking their opinions in the design phase to insure that the resulting system would be "friendly" to operate and would interface easily into operational procedures.

SYSTEM ANALYSIS

We verified and documented the Monitor System using the Yourdon Structured Analysis method. This technique provided a functional description of the complete system, independent of hardware and software.

The Yourdon analysis provided two clear advantages during the design phase:

- Requirement clarification
- Efficient use of manpower

The Yourdon analysis also highlighted redundancy and design problems in both hardware and software. Consequently, we focused our use of manpower appropriately and alleviated communication problems associated with a multi-disciplinary team working in physically separate areas.

For a thorough discussion of the Yourdon method, refer to Tom De Marco's Structured Analysis and System Specification (Yourdon Inc., 1978).

Appendix B provides details of the system in the form of the following: context diagram, data flow diagrams (DFDs), mini-specifications, and a data dictionary. The following descriptions of the system hardware and software are intended to be very general. Refer to Appendix B for more detailed information.

HARDWARE

The Safety Monitor System hardware consists of two distinct subsystems (See Figure 1), one at the Mill/Lathe (local subsystem), the other in the remote control room (remote subsystem).

The local subsystem consists of an LSI-11/2 and a Mux Interface Chassis acting as a latch and buffer. The local LSI-11 sequentially requests 64 8-bit bytes to be latched. After the 64^{th} byte has been latched, the data is sent asynchronously over an RS-232-C line at 9600 baud to the remote control room.

The remote system LSI-11/23 receives the data, validates it, and adds the time and date. This data is then stored in a 1/2 megabyte circular file. In addition, the data is displayed on a monitor which permits the machine tool operator to quickly monitor the entire process (See Figure 2).

If an E-Stop is generated or data transmission stops for any reason, data is transferred from the circular file to a floppy disk. This 15-minute history is then available for off-line review and investigation to determine the precise events leading up to the termination of monitoring.

An uninterruptable power supply (UPS) provides up to 72 hours of power backup capability. With power interruptions a reality at Site 300, the UPS ensures reliable operation during power failures or glitches. The UPS also guarantees that, during an event which interrupts power, the system remains on-line to transfer the data to the floppy disk.

SOFTWARE

We developed four programs to control the monitoring system:

- Downloader (DWNLDR)
- Data acquisition (a separate program, contained in DWNLDR)
- Monitor (DYNMON)
- Search (SEARCH)

The downloader program (written in assembly language) allows the operator to load and start the data acquisiton program on the local LSI-11/2 from the remote control room. The data acquisition program resides in the local LSI-11 and controls the Mux Interface Chassis and data transmission to the remote control station.

Once the real-time data is received at the remote control room, the time and date are added and the data is then stored in the circular buffer. DYNMON, the dynamic monitor program (also written in assembly language), stores the data and displays it on the video display monitor for the operator (Figure 2). DYNMON will also transfer the 15 minutes of history in the circular buffer to a floppy disk if it detects an E-Stop or if the communication with the data acquisition program terminates. Appendix A contains detailed steps on how the operator starts the monitoring process.

Data can be retrieved from the floppy disk after an E-stop command or termination of LSI-11/2 transmission with the SEARCH program (written in FORTRAN and MACRO). SEARCH has a number of capabilities. For instance, it displays data in a table format from any point in the 15-minute interval. Thus, the examiner can move forward or backward in time relating different machine parameters to each other to determine what was happening at any time during the machining cycle. The program is also menu-driven, making it easy for the examiner to access, handle and operate. The maximum number of items that can be displayed at any one time on the terminal depends on the items chosen. In the worst case, the operator can display a minimum of 7 items including the time. In addition, the program has software hooks for future graphics capabilities.

INDUSTRIAL APPLICATIONS

The Safety Monitor System also has applications in industry. The Pantex plant in Amarillo, Texas has high explosives machining requirements very similar to those at Site 300. Several personnel from Pantex visited the HEMF area in July 1982 and were given a tour and demonstration. They now plan to incorporate the Safety Monitor as well as some of the earlier safety modifications into their facility's operation. Thus, they are anxious to see us complete the Safety Monitor so that first-hand experience can be gained in operating the system.

Cincinnati Milicron, which builds machine tools, has also expressed an interest in the Safety Monitor System. Their objective would be to interface the Safety Monitor to their machine so that preselected parameters could be monitored during the warranty period to determine whether the machine had been misused by the user. Personnel at Cincinnati Milicron indicated that other machine tool builders would be interested in a Safety Monitor for the same reason.

CONCLUSION

Our project was to design and install a safety monitor system on a Bostomatic Mill/Lathe used to remotely machine high explosives. The system had to be easy for the operators to incorporate into their operational procedures; it also had to monitor and display real-time data of critical machining parameters, provide reliable data storage, and provide easy access for post-incident analysis. The system was installed and delivered in November 1983. It promises to enhance both the safety and reliability of the mill/lathe's operation.

ACKNOWLEDGEMENTS

We wish to thank the many people who helped and supported us in designing and building this system. We particularly want to mention Don Liston and Mark Verschelden. Don Liston was the engineer responsible for debugging the hardware and evaluating the system before it was delivered. Mark Versheldon provided valuable feedback in the design, received and helped install the system, and helped bring it up.

Absolute Data Display

X position
Y position
Z position
X tool force
Y tool force
Z tool force
Chip thickness
Surface feet per minute
Spindle rpm
Sequence no.

Axes Control

Jog inc.
Jog X
Jog Y
Jog Z

CTC Mode

Run state
Active state

Machine Controls

Axis power
Cycle start
Cycle stop
Feedhold
Spindle power

FH/ES Conditions

X enc.
Y enc.
Z enc.
X tool force
Y tool force
Z tool Force
Spindle Overspeed
CTC
SFM
VAC
Water

TABLE 1. Critical machining parameters

Multiplexor Interface Chassis	LSI 11/2
LSI 11/23	Topaz uninterruptible power supply
Dual floppy disk controller	Dual density, dual floppy disk drive unit
Dynamic Video Display Monitor	4K of VURAM memory
CRT and Keyboard	Elite model 1520, Data Media
Data RAM Bulk Memory	512K Bytes

TABLE 2. List of hardware for the Safety Monitoring System

Bostomatic
CNC
with
Safety
Circuits

Multiplexor
Interface
Chassis

LSI-11/2

DATA

RS-232C (9600 BAUD)
~100 feet

LOCAL MACHINE ROOM

****

Data Media
CRT & Keyboard
Terminal

Dynamic Video
Display Monitor
(Real-Time Data)

RS-232C
LSI-11/23
DATA

UPS

DATA RAM
BULK MEMORY
(512 K BYTES)

DUAL DENSITY
DUAL FLOPPY
DISK

REMOTE CONTROL ROOM

****

Figure 1. Layout of the Safety Monitor System showing the subsystems in the local machine room and the remote control room.

Insert Figure 2.

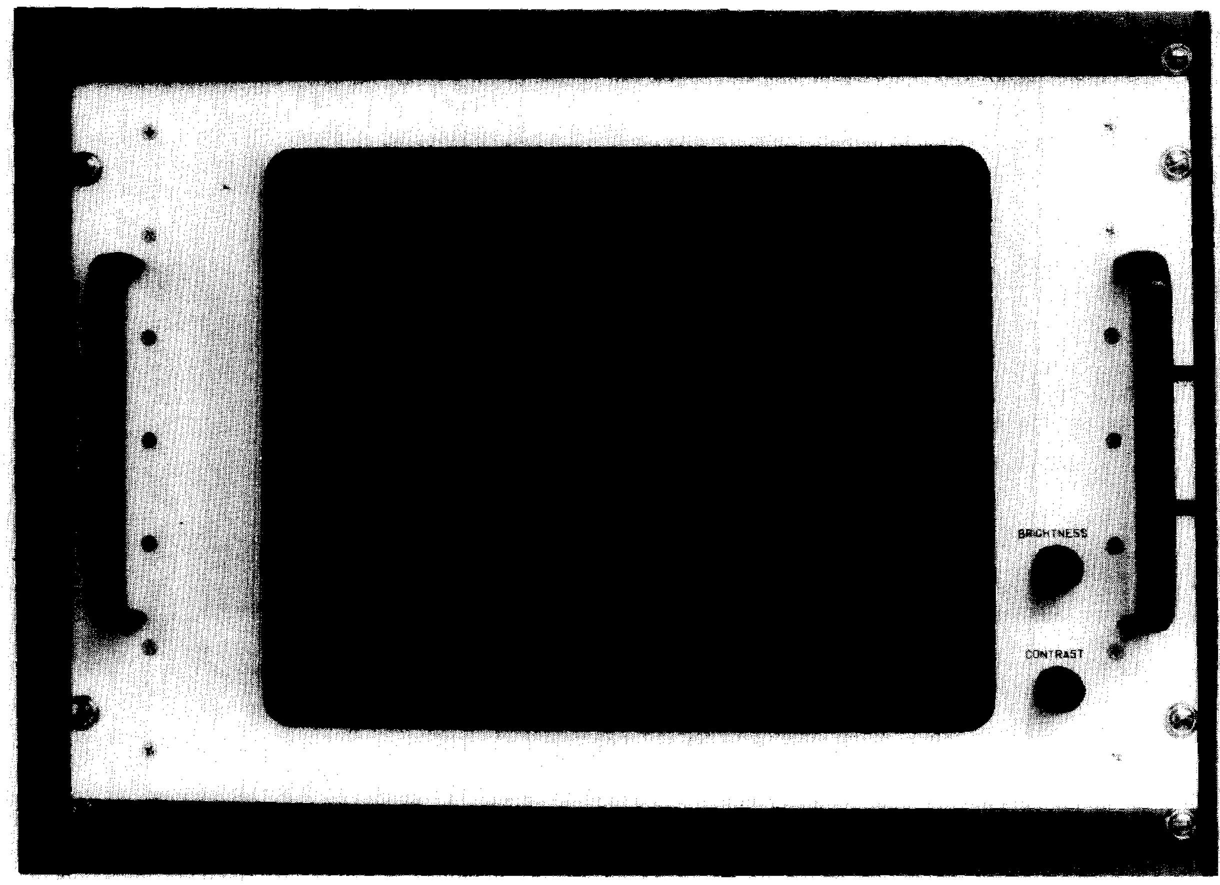


Figure 2. Typical monitor display with data

APPENDIX A

This Appendix includes the following detailed information used in the systems analysis:

- Context diagram
- Data flow diagrams
- Mini-specifications
- Data dictionary

As Tom DeMarco notes in his book Structured Analysis and System Specification, two analysis tools are required for Yourdon systems analysis. First, there must be a way to separate and document system requirements. Second, some way is needed to keep track of and evaluate system interfaces.

Context and Data Flow Diagrams (DFDs) are tools used to separate and help define requirements for the system. Mini-specifications define the terms used in these diagrams. The Data Dictionary defines and evaluates the system interfaces. (For more information, refer to DeMarco's Structured Analysis and System Specification.)

Context Diagram

The context diagram below (Figure A-1) shows how the Safety Monitor System interfaces with the HE machine, the users, and other systems in the machine's environment. Arrows indicate input and output flows. For instance, the CNC machine tool controller sends machine status and control data to the Safety Monitor System. As one output, the Safety Monitor System sends a real-time display of this data to the video display monitor.

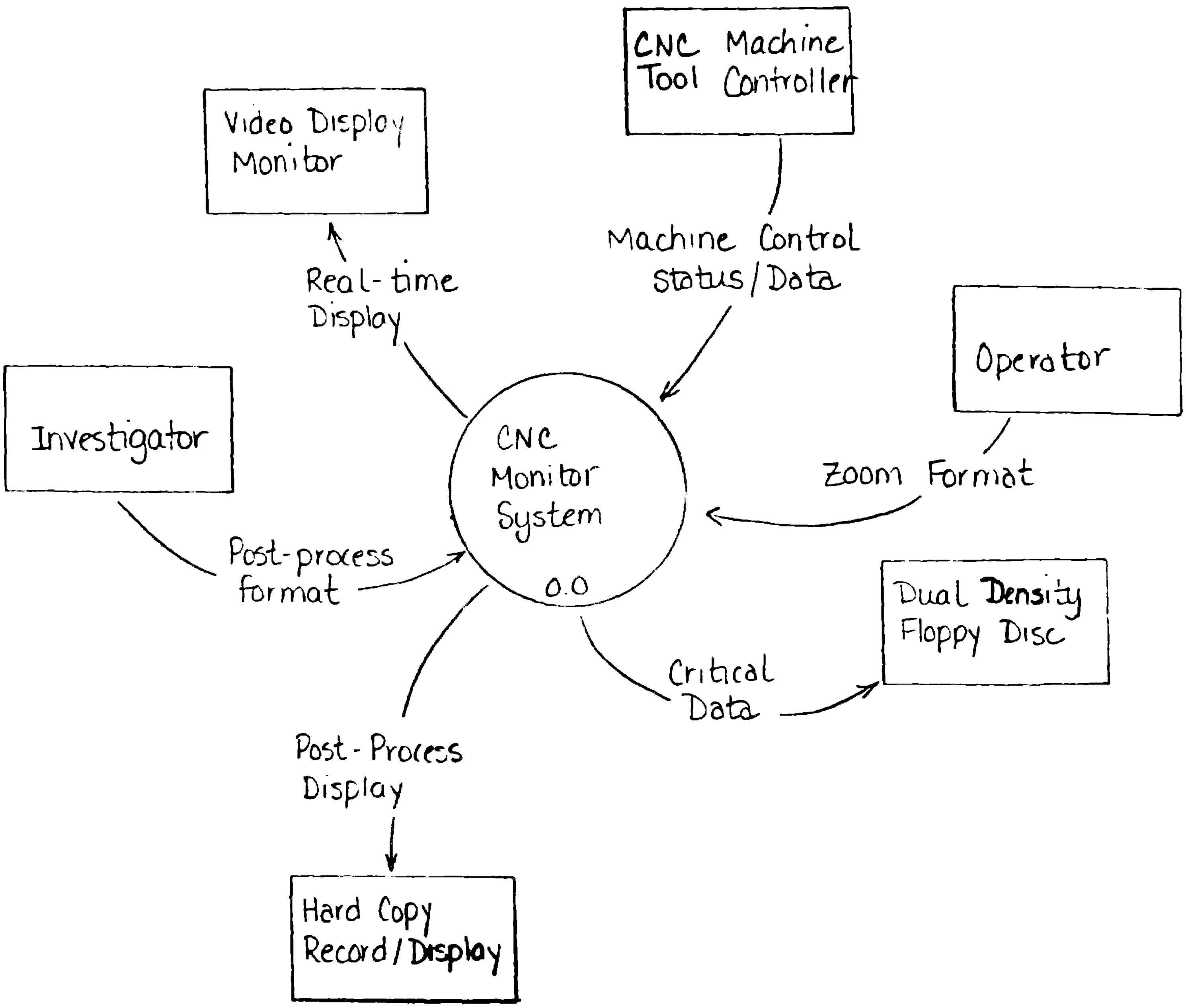


Figure A-1. Context diagram for the CNC Safety Monitor System.

Data Flow Diagrams

The following data flow diagrams (DFDs), Figures A-2 to A-7, are network representations of the Safety Monitor System. The DFDs break down the system into its components and shows the interfaces between these components.

These six DFDs fit together to give a complete and logical picture of the system, beginning with Figure A-2. Figure A-2 is an overall diagram of the entire Safety Monitor System. In this figure, note that each component of the system has a number: "Transmit CNC Data" is 1.0; "Monitor System Status" is 3.0; etc. These component parts are shown in more detail in the figures on the following pages. For instance, Figure A-3 looks at the details of 1.0, or "Transmit CNC Data". Figure A-5 looks at the details of 4.0, or "Update Display". Each of the numbered details in these DFDs (1.0, 2.7, 5.2, etc.) is called a "primitive". For more information on these primitives, turn to the section of this Appendix dealing with Mini-Specifications (pg. 20).

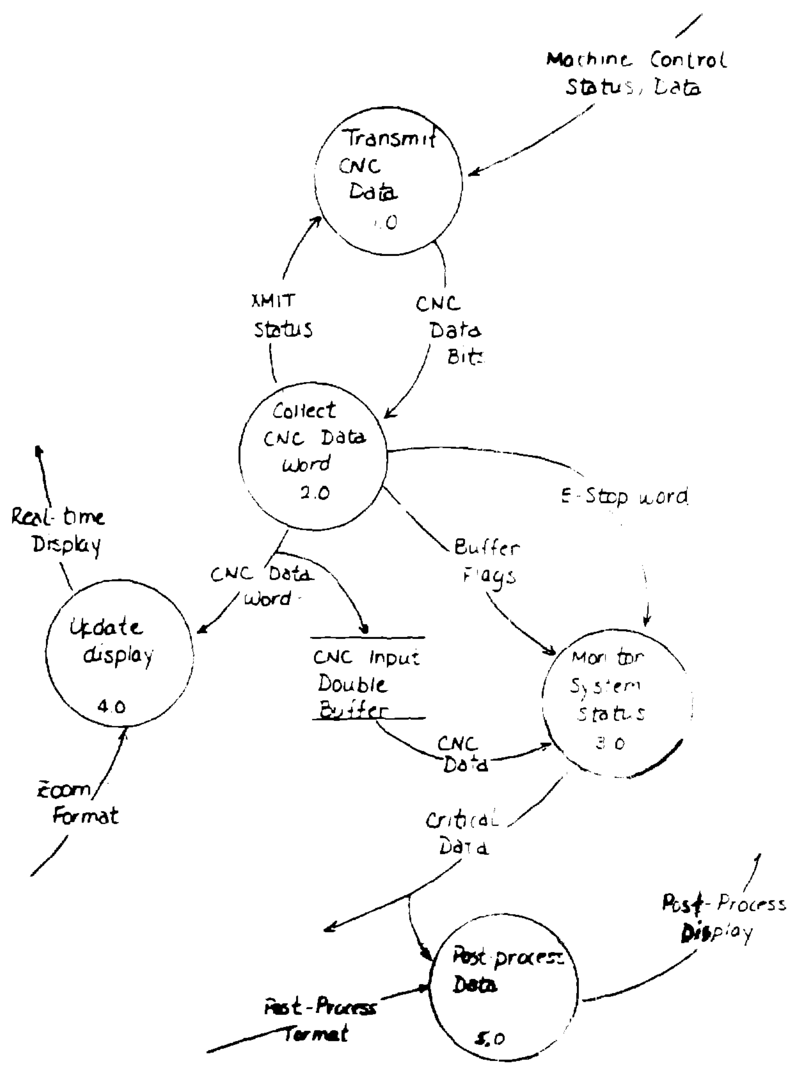


Figure A-2. Overall DFD for the Safety Monitor System showing components.

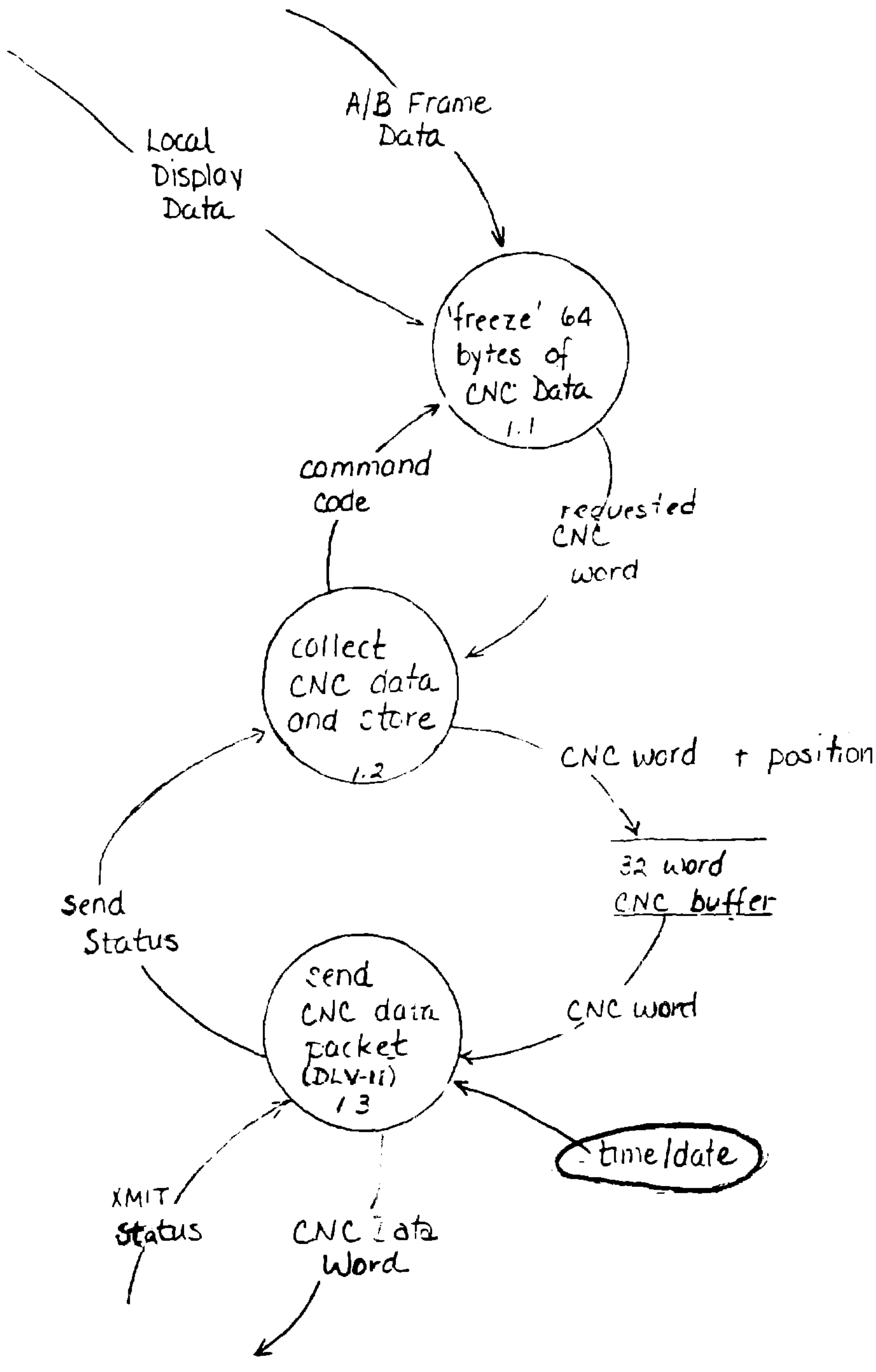


Figure A-3. DFD for component 1.0 "Transmit CNC Data".

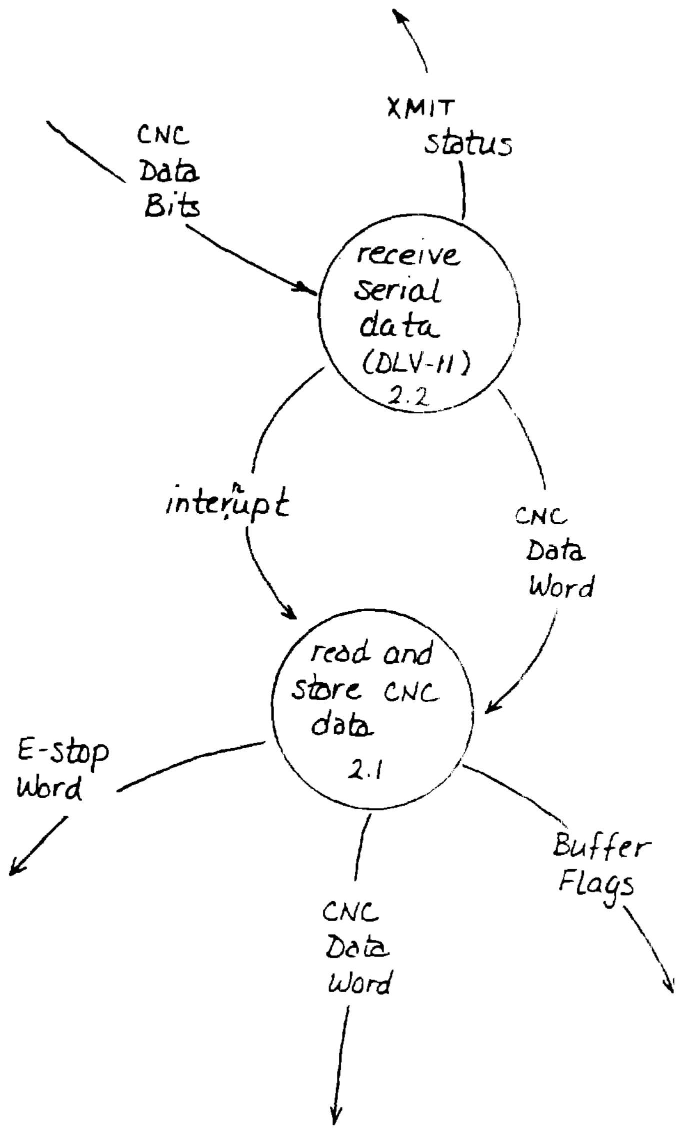


Figure A-4. DFD for component 2.0 "Collect CNC Data Word".

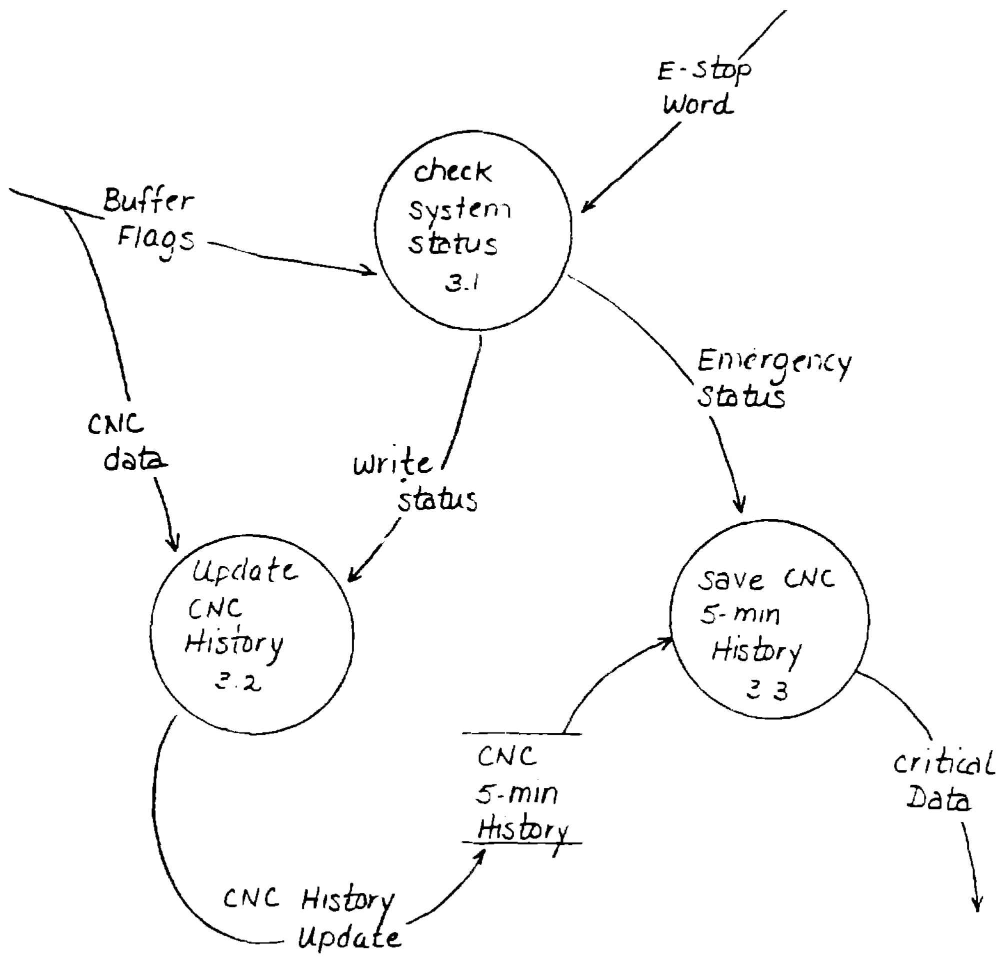


Figure A-5. DFD for component 3.0 "Monitor System Status".

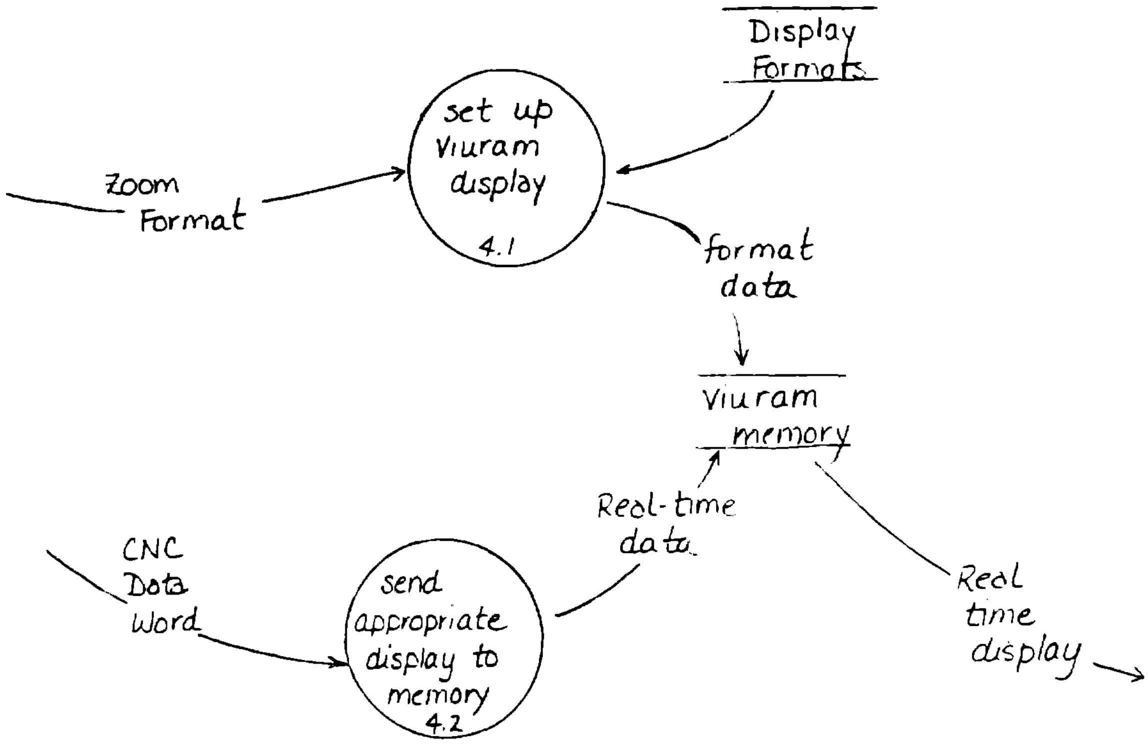


Figure A-6. DFD for component 4.0 "Update Display".

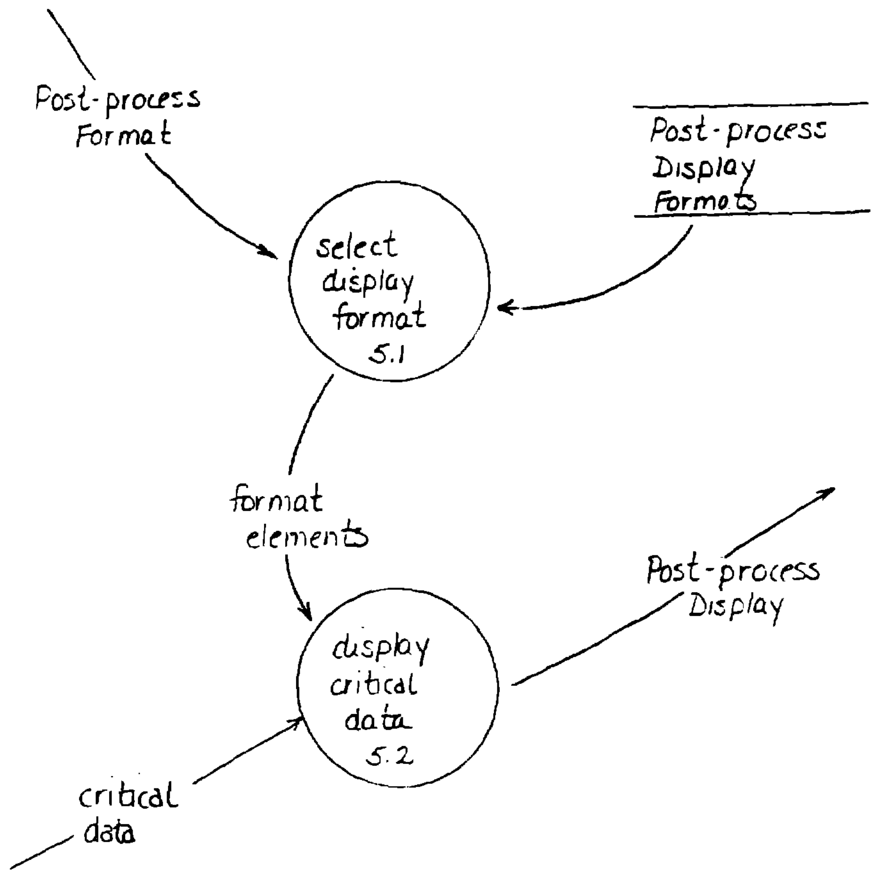


Figure A-7. DFD for component 5.0 "Post-Process Data".

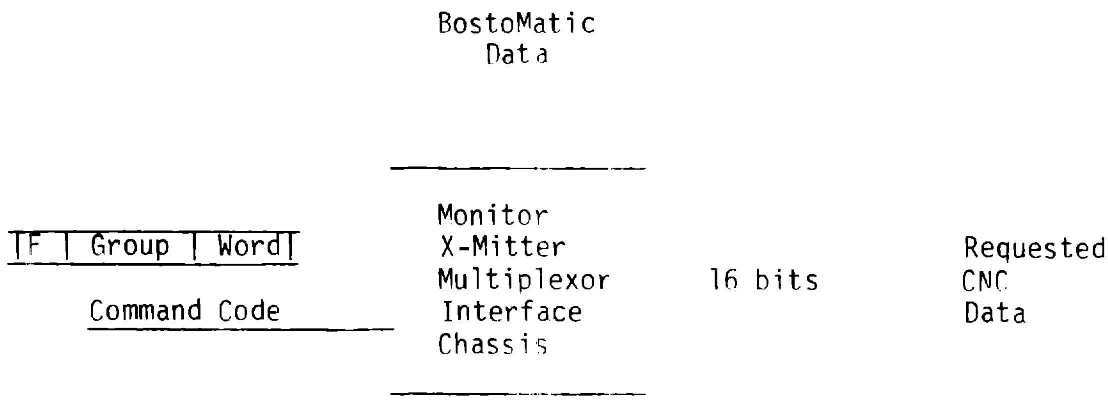
MINI-SPECIFICATIONS

In Yourdan analysis, the mini-specification is "a written description of underlying policy governing transformation of input into output data flows" (pg. 176, Structured Analysis and System Specification). The primitives from the DFDs on the previous pages are defined in the specifications below.

1.1 'Freeze' 64-bytes of CNC Data

1.1.1 If command-code freeze = 0 then Latch A/B-Frame-Data and Local-Display-Data and Format-Codes to Monitor Transmitter-Multiplexor Interface Chassis (LEA 80-1609)

1.1.2 If 4   Group-Number   7 then enable the output of latches specified by Word-Number



1.2 Collect CNC Data and Store

Do while Send-Status = Complete
Set Freeze = On in Command-Word

For each Group-Number

For each Word-Number
Send Command-Word* to DRV-11 (address = 167772)
Read Requested-CNC-Word from DRV-11 (address = 167774)
Store Requested-CNC-Word into next position in 32-Word CNC Buffer

Set Freeze-Off in Command-Word and send to DRV-11

*Command-Word = |F | Group | Word|

F = 0   Freeze On
= 1   Freeze Off

Group-Number = 4, Word-Number = 0   First CNC Word
Group-Number = 7, Word-Number = 7   Last CNC Word

1.3 Send CNC Data Packet

When all 32 CNC Data Words are stored, a DLV-11 (address = 177560) running at 9600 Baud is used to send the CNC data under program status mode.

```
Set Send-Status = not complete

        For each CNC-Word

           For each byte

              If XMIT-Status = 1 (DLV-11 address 177564, bit 7)
                then send 1 byte of CNC-Word (address = 177566) else
                re-check XMIT-Status

Set Send-Status = complete

After 2 32-Word CNC Data Packets, delay 5000 (Mov instr)  80 ms
```

2.1 Read and Store CNC Data

```
Reset Buffer-Flags

Do until 32 CNC-Words are put into CNC-Input-Buffer

        Begin

        If Interrupt = On then
           begin
              read CNC-Word from DLV-11 (address = 175612)
              update Buffer-Flags

              If CNC-Data is not synchronized*
                then reset Buffer-Flags
                else
                begin
                   Put Time/Date** into first 2 buffer positions
                   (i.e., word 1 = day/hour
                         word 2 = minute/second)
                   If Override-Switch = Off
                         and E-Stop-Switch = On
                         then F-Stop-Word = 1
                         else E-Stop-Word = 0
              end
           end
           else
end
next CNC-Word
```

* 4 bytes in a row matching XCODE1, XCODE2, XCODE3, XCODE4
**Time/Date are loaded from the following addresses:

Day @ 160770
Hr/Min @ 160772
Second @ 160774

2.2 Receive Serial Data

This function is performed by a DLV-11 (address = 175610) running at 9600 Baud in the Remote LSI-11 under interrupt.

Receiver CSR address = 175610_8
Receiver Buffer address = 175612_8
Interrupt Vector address = 330_8

interrupt enable = bit 6
interrupt = bit 7

3.1 Check System Status

```
If E-Stop-Word = 1      then Emergency-Status = On
                        else Emergency-Status = Off

If Buffer-Flags indicate buffer is full
                        then begin
                           Buffer-Flags point to other buffer
                           Write-Status = Write
                           end
                        else     Update SHTDWN counter

If SHTDWN counter   maxlim then Emergency-Status = On
```

3.2 Update CNC History

The CNC = 5-Min-History is a circular buffer residing on a bulk memory device (DataRam). The bulk memory looks like an RK-11, fixed-head disk and utilizes the RK-11 device handler.

```
If Write-Status = Write
       then  write the contents of the CNC-Input-Buffer to the
             CNC-5-Min-History (bulk memory) at the end of the
             circular buffer
             If bulk memory is full then overwrite the oldest buffer
             of data
```

3.3 Save CNC 5-Min History

```
If Emergency-Status = On
       then write entire contents of the CNC-5-Min-History (bulk
       memory) to floppy disc
```

4.1 Set Up VIURAM Display

The VIURAM is a Q-bus interfaced device that provides an alphanumeric display to a standard video monitor. The interface uses an M6845 microprocessor as a device controller. The display is 24 x 80 characters, addressed from 0 to 3577_8. Chapter IV (p. 25) of the "VIURAM-011 User Manual" provides programming information.

To set up the VIURAM:

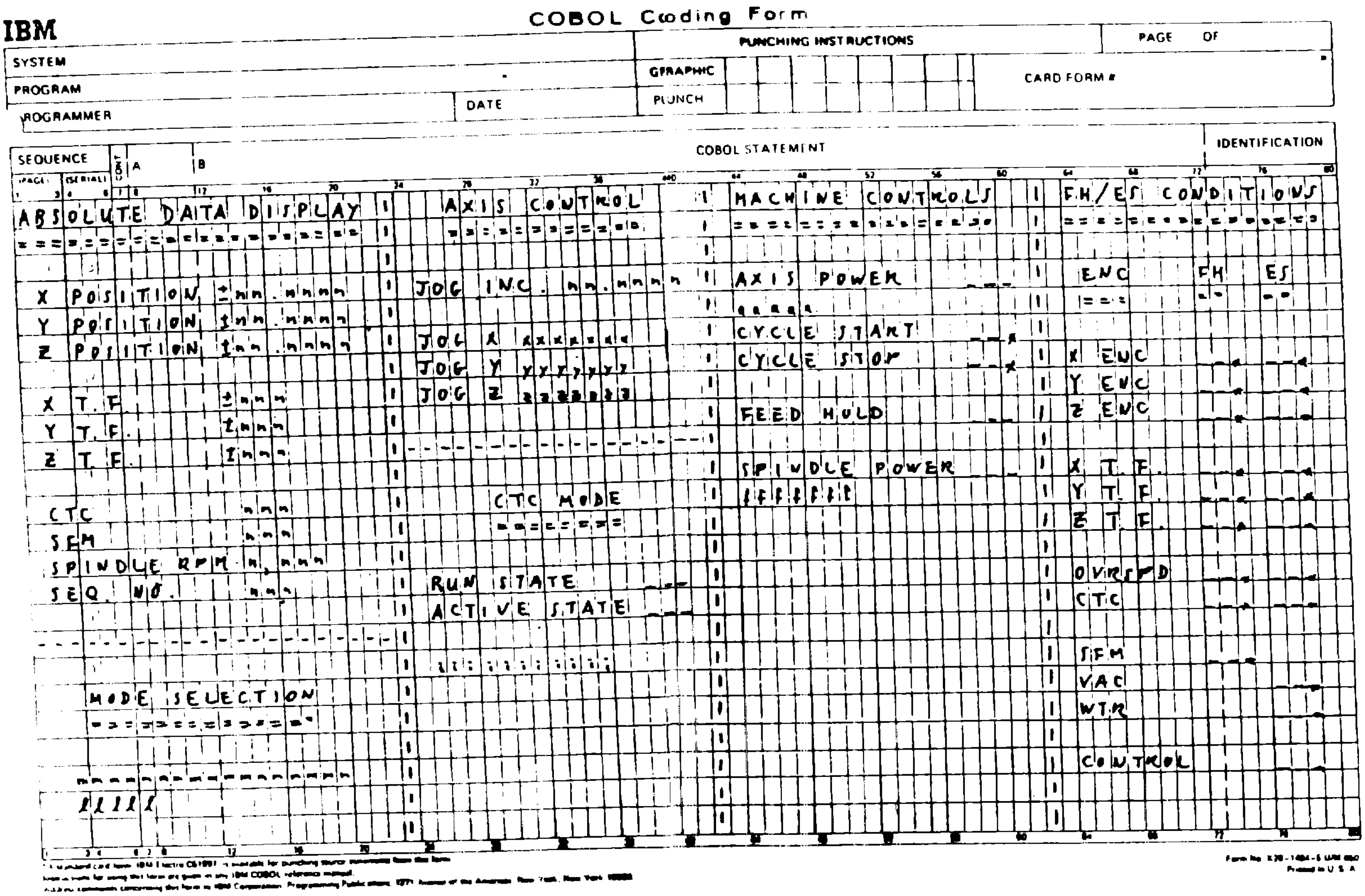
1) Set up the 16 controller (M6845) registers to generate proper video timing
2) Clear the video display memory
3) Send out the display as highlighted (in pink) on next page

4.2 Send Appropriate Display to Memory

Complete the display as highlighted (in green) using the most recent CNC-Data according to the following key:

5.1 Select Display Format

See Figure A-8 below.


IBM COBOL Coding Form

SYSTEM
PROGRAM
PROGRAMMER
DATE
PUNCHING INSTRUCTIONS
GRAPHIC
PUNCH
PAGE OF
CARD FORM #
SEQUENCE (PAGE) (SERIAL)
A B
COBOL STATEMENT
IDENTIFICATION

ABSOLUTE DATA DISPLAY | AXIS CONTROL | MACHINE CONTROLS | FH/ES CONDITIONS
X POSITION ±nn.nnnn | JOG INC. nn.nnnn | AXIS POWER | ENC FH ES
Y POSITION ±nn.nnnn
Z POSITION ±nn.nnnn | JOG X xxxxxxx | CYCLE START
JOG Y yyyyyyy | CYCLE STOP | X ENC
JOG Z zzzzzzz | Y ENC
X T.F ±nnn | FEED HOLD | Z ENC
Y T.F. ±nnn
Z T.F. ±nnn
SPINDLE POWER | X T.F.
CTC nnn | CTC MODE | ffffffff | Y T.F.
SFM nnn | Z T.F.
SPINDLE RPM n,nnn
SEQ. NO. nnn | RUN STATE | OVRSPD
ACTIVE STATE | CTC
SFM
MODE SELECTION | VAC
WTR
CONTROL
lllll

Figure A-8.

5.2 Display Critical Data

± display an ASCII "t" if sign = 0
display an ASCII "-" if sign = 1

n display ASCII equivalent for each digit of the data element specified

mm...m

INITIALIZE	if	Mode-Selector-Word	bits	7-0	=	00000001
JOG	"	"	"	"	=	00000010
ORGIN	"	"	"	"	=	00000100
MANUAL	"	"	"	"	=	00001000
SEARCH SINGLE	"	"	"	"	=	00010000
SEARCH CONTINUOUS	"	"	"	"	=	00100000
TAPE SINGLE	"	"	"	"	=	01000000
TAPE CONTINUOUS	"	"	"	"	=	10000000

... MILL if Mill-Status = 1
LATHE if Lathe-Status = 1

On if the status of the data element is = 1 (on)
blank otherwise

If Jog-Status = 1 then display JOG X XXXXXXX
JOG Y YYYYYYY
JOG Z ZZZZZZZ

where XX...X = LEFT if Jog-Direction-Status = 000001
= RIGHT " " " = 000010

YY...Y = IN if Jog-Direction-Status = 000100
= OUT " " " = 001000

ZZ...Z = UP if Jog-Direction-Status = 010000
= DOWN " " " = 100000

else display blanks

aa...a AUTO if (Tape-Single-Status or Tape-Continuous-Status) = 1
else dislplay blanks

ff...f FORWARD if Forward-Status = 1
REVERSE if Reverse-Status = 1
blank if (Forward-Status and Reverse-Status) = 0

ii...i INCHES
MILLIMETERS

DATA DICTIONARY

"A Data Dictionary is an ordered set of definitions of terms used in a DFD" (pg. 129, Structured Analysis and System Specification). Every term used in the DFDs to analyze the Safety Monitor System is listed in this Data Dictionary.

```
A/B Frame Data =      CTC Word
                    + SFM Word
                    + Sequence Number Word
                    + EStop Status Word
                    + FH Status Word
                    + FP Control Word
                    + Mode Selector Word
                    + Jog Status Word

Bit = [0|1]

Buffer Flags = Adress  ** current address **
              +Lastad ** last address used **
              +Shtdwn ** com-link counter **

                 16
CNC Data Bits =    {bit}
                    ** 2 bytes of CNC data @ 9600 baud **

                 16
CNC Data Word =    {bit}
               ** CNC Word plus what kind of data it contains **

CNC History Update = Machine Control Status/Data
                   ** most recent buffer of CNC data **

            16
CNC Word =    {bit}

Command Code = Freeze + Group Number + Word Number
                  65      3 2      0
               ** |_|______|_______| **

               4        3
Critical Data = 5 min History
              ** all data currently stored in bulk memory **

                                                     14
Control Word1 = E Stop Switch + Override Switch +      {bit}
                ** wired from E Stop Status Word **
```

Control Word2 = FH Switch + FH Overide Switch + ${}^{14}\{\text{bit}\}$
** wired from FH Status Word **

CTC Word = {bit} + {digit}

```
    15                                                   0
** | unused | digit        | digit        | digit        | **
```

DRC Meter LSB Word = ${}^{4}\{\text{digit}\}$

```
    15                                                   0
** | digit  | digit        | digit        | digit        | **
```

DRC Meter MSB Word = ${}^{6}\{\text{bit}\}$ + sign + overflow + ${}^{2}\{\text{digit}\}$

```
    15                                                   0
** | unused         |   |   | digit        | digit        | **
```

-overflow

-sign

Emergency Status = [on|off]

E-Stop Status Word = ${}^{7}\{\text{bit}\}$

+ Control ES Status

+ CTC ES Status

${}^{2}\{\text{bit}\}$

+ Tool Force ES STatus

+ Spindle Overspeed ES Status

+ Z Encoder ES STatus

+ Y Encoder ES Status

+ X Encoder ES Status

**	15	8	7	6	5	4	3	2	1	0	**

- X Encoder ES Status
- Y Encoder ES Status
- Z Encoder ES Status
- Spindle Overspeed ES Status
- Tool Force ES Status
- CTC ES Status
- Control ES Status

X Encoder ES Status = [0|1]

Y Encoder ES Status = [0|1]

Z Encoder ES Status = [0|1]

Spindle Overspeed ES Status = [0|1]

Tool Force ES Status = [0|1]

CTC ES Status = [0|1]

Control ES Status = [0|1]

<u>FH Status Word</u> = $^{4}\{\text{bit}\}$

+ Water FH Status

+ Vacuum FH Status

+ SFM FH Status

+ $^{1}\{\text{bit}\}$

+ CTC FH Status

$^{2}\{\text{bit}\}$

+ Tool Force FH STatus

+ Spindle Overspeed FH Status

+ Z Encoder FH Status

+ Y Encoder FH Status

+ X Encoder FH Status

```
     15                          11 10 9    7  6  5  4  3  2  1  0
** |                            |  |  |  |  |  |  |  |  |  |  |  |  | **
                                                                   - X Encoder FH Status
                                                                - Y Encoder FH Status
                                                             - Z Encoder FH Status
                                                          - Spindle Overspeed FH Status
                                                       - Tool Force FH Status
                                              - CTC FH Status
                                        - SFM FH Status
                                     - Vacuum FH Status
                                  - Water FH Status
```

<u>X Encoder FH Status</u> = [0|1]
<u>Y Encoder FH Status</u> = [0|1]
<u>Z Encoder FH Status</u> = [0|1]

<u>Spindle Overspeed FH Status</u> = [0|1]

<u>Tool Force FH Status</u> = [0|1]

<u>CTC FH Status</u> = [0|1]
<u>SFM FH Status</u> = [0|1]
<u>Vacuum FH Status</u> = [0|1]
<u>Water FH Status</u> = [0|1]

FP Control Word = ${}^{6}\{\text{bit}\}$

+ Feedhold Status

+ Auto Status

+ ${}^{2}\{\text{bit}\}$

+ Reverse Status

+ Forward Status

+ Spindle Power Status

+ Lathe Status

+ Mill Status

+ Axis Power Status

```
   15                   9         5  4  3  2  1  0
** |____________________|__|__|__|__|__|__|__|__|__| **
                                                - Axis Power Status
                                             - Mill Status
                                          - Lathe Status
                                       - Spindle Power Status
                                    - Forward Status
                                 - Reverse Status
                         - Auto Status
                      - Feedhold Status
```

Axis Power Status = [0|1]

Mill Status = [0|1]

Lathe Status = [0|1]

Spindle Power Status = [0|1]

Forward Status = [0|1]
Reverse Status = [0|1]

Auto Status = [0|1]

Feedhold Status = [0|1]

Format Codes = XCODE1
XCODE2
XCODE3
XCODE4

Freeze = [0|1]
** 0 = on **

Group Number = |100| ** First CNC group **
|101|
|110|
|111| ** Last CNC group **

Interrupt = [on|off]

Jog Direction Status =

0	0	0	0	0	0	** neutral **
0	0	0	0	0	1	** Jog X Left **
0	0	0	0	1	0	** Jog X Right **
0	0	0	1	0	0	** Jog Y In **
0	0	1	0	0	0	** Jog Y Out **
0	1	0	0	0	0	** Jog Z Up **
1	0	0	0	0	0	** Jog Z Down **

Jog Inc Status =

0	0	0	0	0	0	1	** .0001 **
0	0	0	0	0	1	0	** .001 **
0	0	0	0	1	0	0	** .01 **
0	0	0	1	0	0	0	** .1 **
0	0	1	0	0	0	0	** 1. **
0	1	0	0	0	0	0	** 4. **
1	0	0	0	0	0	0	** 10 **

Jog Status Word = $^{2}\{\text{bit}\}$

+ Jog Direction Status

+ $^{1}\{\text{bit}\}$

+ Jog Inc Status

**	15	13	7	6	0	**
**		Jog Direction Status		Jog Inc Status		**

Local Display Date = Spindle RPM Word
+ Position Data
+ Tool Force Data

Machine Control Status/Data =	
XCODE1 + XCODE2	** Code1 + Code2 **
+XCODE3 + XCODE4	** Code3 + Code4 **
+Control Word1	** Code5 + Code6 **
+Control Word2	** Code7 + Code8 **
+E Stop Status Word	** Code9 + Code10 **
+FH Status Word	** Code11 + Code12 **
+FP Control Word	** Code13 + Code14 **
+ $^{16}\{\text{bit}\}$	** Code15 + Code16 **
+Mode Selector Word	** Code17 + Code18 **
+Jog Status Word	** Code19 + Code20 **
+CTC Word	** Code21 + Code22 **
+SFM	** Code23 + Code24 **
+Spindle RPM Word	** Code25 + Code26 **
+ $^{16}\{\text{bit}\}$	** Code27 + Code28 **
+ $^{16}\{\text{bit}\}$	** Code29 + Code30 **
+ $^{16}\{\text{bit}\}$	** Code31 + Code32 **

+X Axis Position LSB Word	** Code33 + Code34 **
+X Axis Position MSB Word	** Code35 + Code36 **
+Y Axis Position LSB Word	** Code37 + Code38 **
+Y Axis Position MSB Word	** Code39 + Code40 **
+Z Axis Position LSB Word	** Code41 + Code42 **
+Z Axis Position MSB Word	** Code43 + Code44 **
+ Sequence Number Word	** Code45 + Code46 **
+ ^{16}{bit}	** Code47 + Code48 **
+ ^{16}{bit}	** Code49 + Code50 **
+ ^{16}{bit}	** Code51 + Code52 **
+ ^{16}{bit}	** Code53 + Code54 **
+X Tool Force Word	** Code55 + Code56 **
+ ^{16}{bit}	** Code57 + Code58 **
+Y Tool Force Word	** Code59 + Code60 **
+ ^{16}{bit}	** Code61 + Code62 **
+Z Tool Force Word	** Code63 + Code64 **

<u>Mode Selector Word</u> = $^{4}\{\text{bit}\}$

+ CTC Active Status

+ CTC Run Status

+ Cycle Stop Status

+ Cycle Start Status

+Tape Continuous Status

+ Tape Single Status

+ Search Continuous Status

+ Search Single Status

+ Manual Status

+ Origin Status

+ Job Status

+ Initialize Status

```
   15                                                   0
** |_________________|___|___|___|___|___|___|___|___|___|___|___|___| **
```

- Initialize Status

- Jog Status

- Origin Status

- Manual Status

- Search Single Status

- Search Continuous Status

- Tape Single Status

- Tape Continuous Status

- Cycle Start Status

- Cycle Stop Status

- CTC Run Status

- CTC Active Status

<u>Initialize Status</u> = [0|1]
<u>Jog Status</u> = [0|1]
<u>Origin Status</u> = [0|1]

<u>Manual Status</u> = [0|1]
<u>Search Single Status</u> = [0|1]
<u>Search Continuous Status</u> = [0|1]

<u>Tape Single Status</u> = [0|1]
<u>Tape Continuous Status</u> = [0|1]

<u>Cycle Start Status</u> = [0|1]
<u>Cycle Stop Status</u> = [0|1]

<u>CTC Run Status</u> = [0|1]
<u>CTC Active Status</u> = [0|1]

SFM Word = ${}^{4}\{\text{bit}\} + {}^{3}\{\text{digit}\}$

	15			0	
**	unused	digit	digit	digit	**

Spindle RPM Word = ${}^{4}\{\text{bit}\} + {}^{3}\{\text{digit}\}$

	15			0	
**	unused	digit	digit	digit	**

X Axis Position LSB Word = DRC Meter LSB Word

X Axis Position MSB Word = DRC Meter MSB Word

Y Axis Position LSB Word = DRC Meter LSB Word

Y Axis Position MSB Word = DRC Meter MSB Word

Z Axis Position LSB Word = DRC Meter LSB Word

Z Axis Position MSB Word = DRC Meter MSB Word

X Tool Force Word = Weston Meter Word

Y Tool Force Word = Weston Meter Word

Z Tool Force Word = Weston Meter Word

Position Data = X Position LSB Word + X Position MSB Word

+ Y Position LSB Word + Y Position MSB Word

+ Z Position LSB Word + Z Position MSB Word

Requested CNC word = ^{16}\{digit\}

** 16-bits of CNC data corresponding to command code **

Sequence Number Word = ^{4}\{bit\} + ^{3}\{digit\}

15 unused	digit	digit	digit 0

Send Status = [complete|not complete]

Time/date = hours + minutes + seconds + day

hours =
** $0 \leq$ hours ≤ 24 **

seconds =
** $0 \leq$ seconds ≤ 60 **

day =
** $1 \leq$ day ≤ 365

Tool Force Data = X Tool Force Word

+ Y Tool Force Word

+ Z Tool Force Word

Weston Meter Word = ^{4}\{bit\} + EOC + sign + overflow + HOB + ^{2}\{digit\}

15 unused					digit	digit 0

-HOB

-overflow

-sign

-EOC

HOB = [0|1] ** high order bit-blank or 1 **

EOC = [0|1] ** end of conversion-status of meter **

sign = [0|1] ** 0 = +, 1 = - **

digit = [0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9] * 4-BCD digits each **

overflow = [0|1]

status = [0|1] [0|1]

Word Number = |000| ** First word **

|001|

|010|

|011|

|100|

|101|

|110|

|111| ** Last Word **

Write status = Buffer Full
Buffer Not Full

XCODE1 = 10101010
** 252_8 **

XCODE2 = 10101010
** 252_8 **

XCODE3 = 01010101
** 125_8 **

XCODE4 = 01010101
** 125_8 **

XMIT Status = [0|1]
** bit 7 of CSR **

APPENDIX B

To start the monitoring process, the operator must do the following from the remote control room:

1. Load the double-density formatted floppy disk in the DY1:'s drive.

2. Type "@SY:MSTART" at the LSI-11/23's terminal. MSTART.COM, the indirect command file, does the following:

   2.1 Initializes the floppy disk in DY1: and the Bulk Core RF:
   2.2 Runs DWNLDR
   2.3 Runs DYNMON